



DIRECT's Plan for Exploration Beyond LEO – July 20, 2009

Finding good answers to the questions before the Exploration Beyond LEO Subcommittee has been a driving force for some members of DIRECT team since before the Vision for Space Exploration (VSE) was even announced. Spacecraft configurations, Launch System capabilities and Mission objectives have always been tightly coupled with complex interactions and interdependences. Making the task before this subcommittee even more difficult is the limited time available for the members to accurately frame and then simplify these complex and highly interactive options for the policy makers. This paper will attempt to distill the experience gained by the DIRECT team as we have wrestled with the same questions.

In order to improve our understanding of the decision domain, the DIRECT team has consistently sought out individuals that represent the full spectrum of opinions within the space exploration community. In fact these discussions have even included those who question the need for space exploration altogether in any form, human or robotic. The cumulative effects of these interchanges have been invaluable in helping us evolve the key recommendations of the DIRECT plan as it exists today. Unfortunately many individuals within competing camps are reluctant to talk to each other. When they do they tend to talk past one another. Fortunately, by keeping an open mind as we listened to the various view points, we found that these seemingly irreconcilable views contained a number of good ideas. We also found that the best ideas from these various sources actually work well together and form a mutually reinforcing system that is clearly better than the sum of its parts.

The several mission approaches identified by the Exploration Beyond LEO Subcommittee are an excellent consolidation of the various options we have considered and form a good back drop from which to explain the benefits of the DIRECT plan, namely;

- 1) Lunar Base (Baseline: Constellation, Polar Base)
- 2) Lunar Global (Lunar Sortie + Robots)
- 3) Moon to Mars (i.e.; what DIRECT calls Mars Forward)
- 4) Mars First (Skip the Moon altogether)
- 5) Flexible Path (Deep Space followed by Surface Access capability)

While the mission approaches at first glance appear to be competitive, we have found that the best mission approach is one that consolidates all approaches into a cohesive plan. We also found that consolidation can also effectively address the key questions facing the members of this subcommittee namely;

- (1) What are the appropriate destinations and sequences of exploration for human exploration beyond LEO
- (2) What should be the mode of surface exploration (if any)
- (3) What is the strategy within the human space flight program for coordinating human and robotic exploration
- (4) What are the assumed launch vehicle(s) to LEO (in terms of mass to orbit and shroud diameter)
- (5) What are the options for in-space fuel/oxidizer storage and transfer
- (6) What is the role that space technology research and development will play
- (7) What is our strategy for engaging international partners in the development of the program
- (8) What is our strategy for engaging commercial entities

These questions are not only highly interrelated but also interact with the five mission approaches described above. Adding to this complex decision environment is that paradigm shifts in technology have historically disrupted even the best made plans. Some of these possible shifts in the technology paradigm, commercially supplied orbital propellant depots for example, will improve some conservative plans well beyond their initial capabilities while they may at the same time be required by others before they have any significant capability at all. This uncertainty and the broad applicability of most potential advancements to all approaches, require that any near term assessment be made within the context of proven technologies. The key is that all approaches under review should maintain a useful budget margin over mission and launch operations costs in order to fund a diverse portfolio of potential improvements spanning the complete range of technology readiness levels. Further, the funding levels of the various elements within this portfolio should be based on the probability corrected assessment of the system wide benefits should these new technologies enter service.

If history is any guide the search for solutions that enable the cost effective expansion of space exploration and development will continue to generate many unintended benefits, benefits that even those who don't support space exploration as a worthy objective in its own right would recognize as positive returns on that investment. Maintaining the ability to mature innovative ideas into more cost effective approaches is an essential element of all viable plans. Doing so enables the gradual and even revolutionary increase in our space exploration capabilities over time within a fixed budget while simultaneously increasing the support of those who have not traditionally been advocates of space exploration. The fact that a particular approach requires advances in technology before it becomes useful should not be seen as an advantage over approaches that do not, as all good plans enable advances in technology and can leverage them.

The ability to replace key elements within the initial approach with more capable and/or cost effective approaches over time, comparable to the shift from Space Shuttle to Jupiter, will necessarily be an important aspect of whatever course is selected. The ability to incorporate improvements within a fixed budget will entail the retirement of past approaches in order to free up resources needed to implement the better solutions. Thus the DIRECT team's advocacy of an inline shuttle derived high volume heavy lift launch system should not be seen as a permanent solution but the best one now based on current technologies. Thus we believe it would be unwise to recommend any path in the next two months based on hoped for technologies or projected economies of scale that may or many not come to fruition.

It should also be recognized however that the Jupiter Launch System specifically addresses many of the serious issues facing our policy makers in the next two months; the most critical of which are nearing a point of no return. It would be indeed unfortunate if we once again destroy an existing system and workforce in favor of other paths that will remain options long into the future, like mandating existing launch systems. With that fact in mind we will describe how the DIRECT plan is a good starting point from which to resume the advance of space exploration beyond LEO while simultaneously not constraining our long term options or possibilities.

Of all the presentations given before the Committee on June 17th only the DIRECT team fully expanded upon the broader advantages of our plan as represented by the key questions facing the members of this subcommittee. We are indeed thankful for the wisdom shown in forming this subcommittee so that a broader set of longer range policy issues can be addressed. Ultimately it is these policy issues that should drive the evaluations of various implementation plans and Launch system requirements. At the same time the Jupiter Launch System will solve the nearer term problems of an extended gap in American based access to the nearly completed International Space Station (ISS)

and the imminent destruction of America's second heavy-lift system and workforce. These near term advantages should and will color any longer term considerations in the direction of policy overall. Whether intended or not, the pending destruction of our current heavy lift industrial base is a trait that all non-Shuttle Derived Heavy Lift proposals, including the current NASA plan, share. The Jupiter Launch System was specifically designed to avoid this future by building upon our existing heavy-lift infrastructure and workforce. While the Jupiter Launch System is politically expedient, especially for a number of key members in Congress, it's equally important to realize that the DIRECT plan also advances a much broader set of longer term national objectives. These objectives have a political support base well beyond the States and Congressional districts that benefit directly from the jobs provided by NASA.

The DIRECT plan is most closely related to option three (i.e. the Moon to Mars) approach identified by the subcommittee. The DIRECT plan has also incorporated many of the benefits associated with other mission paradigms. But before we can build a bridge beyond LEO we must first consider building a bridge between the current International Space Station (ISS) partnerships and technologies to the VSE. Discussions with ISS partners indicate that they are very open to funding a follow on project that builds on their past and existing commitments to the ISS.

The ISS partners were very interested in development of a large ground integrated long duration autonomous habitat (i.e. ISS 2.0) to be tested at ISS 1.0 (the existing Space Station). They agreed that this would be an excellent mechanism not only to build upon the lessons learned at the ISS 1.0 but to make their current support of ISS 1.0 mission directly relevant to the VSE. They also agreed that this connection between their past investments in ISS 1.0 was essential in order for them to persuade their governments to fund new initiatives like VSE. Under this aspect of the DIRECT plan the ISS 2.0 acts as bridge between ISS 1.0 and VSE thus enabling a path for the ISS 1.0 experience base, technology and partnerships to advance into the new initiative.

The primary specification of ISS 2.0 is that it be the proto-type for all subsequent long duration habitats placed on the Lunar surface, used for travel in Deep Space to Near Earth Objects (NEO) and ultimately for Mars. Once the ISS 2.0 has proved itself while docked to ISS 1.0 the lessons learned would then be incorporated into all subsequent Long duration habitats whether used for Deep Space Transits or hostile Surface Habitation. The Lunar surface base application need not necessarily be the first use of this new capability. Should our ability to sustain human life reliable over long durations and at great distances mature before our ability to land and return from deep gravity wells like the Moon does missions to Near Earth Objects (NEO) could well occur before the first Lunar surface mission. In some respects the lower gravity well of a NEO makes them easier than missions to the Lunar surface. At the same time NEO missions will also be less tolerant of problems should they arise because of the limited crew return capabilities vs the Moon. In the end it comes down to which technology is available when. This is not unlike how the Apollo-8 mission was created after the delay in the Lunar lander development materialized. In this regard the DIRECT plan incorporates key aspects of mission approach 5 in which Deep Space capability could occur before or even in conjunction with Lunar surface missions. These are not mutually exclusive capabilities in our view because one reinforces the other. Both capabilities are ultimately needed before the Mars mission can be undertaken. Their order is not as important as the ability to do them both reliably at some point in time and within the available budget. By making one a minor variation of the other we can achieve both.

At the geopolitical level this long duration habitat development effort could be a key mechanism for combining the efforts of all nations interested in becoming an integral part of the American lead effort beyond LEO. In this way the return to the Moon and/or NEO missions could both be international in scope and funding from the earliest planning stages. Under the DIRECT plan the United States using just its own transportation infrastructure (i.e. Jupiter Core- EDS – Orion – Altair) could perform Lunar sortie missions akin to Apollo and achieve mission approaches 1 and 2 without international support. On the other hand by combining this US based transportation system with the internationally developed long duration surface habitat we could deliver more than a hundred times the Lunar surface hours of the entire Apollo program in one mission while requiring no more money than what the United States currently spends on ISS/Shuttle mission in one year. By working together all partner nations will achieve much more in a shorter period of time than they could ever hope to accomplish apart. All enduring partnerships are based on this simple principle. The opening up of Space for all mankind will serve as positive example of how that same behavior can improve life for everyone living on the spaceship we call Earth. This will enable VSE to become a true international effort enabling 100 fold increase over Apollo all while requiring less than half the money per year as Apollo. By any measure this would deliver results far beyond a nostalgic repetition of America's past beyond earth orbit accomplishments. Rather this accomplishment represents an important technical and societal bridge we must cross before going on to Mars.

The first step in the development of this long duration Lunar surface mission architecture would be to land an internationally developed Lunar Base Surface habitat on the Moon using a dual launch Jupiter-241 approach. The first launch would place the Earth Departure Stage (EDS) into Earth orbit followed by the second launch containing the high volume, high mass, ground integrated and tested long duration habitat unit. Using this approach the landed mass of the habitat unit could be over 40mT and up to 60mT using a commercially supplied orbital propellant depot to top off the EDS. The second step would be to deliver the international crew to the Lunar surface in a like fashion in which the EDS places Orion and Altair on a Lunar trajectory. One Lunar surface mission in this scenario would require 4 Jupiter launches, 1 Orion, 1 Altair and 1 Habitat. This approach would enable long duration lunar surface missions for 6-12 months for a crew of 4-6. The habitat would also be moved periodically, as intended on current Mars mission plans, in order to expand the range of exploration. The primary objective would be to test surface equipment and operational concepts for Mars minus the Mars Entry, Descent and Landing (EDL) systems. Given the proximity of the Earth, most potential equipment failures on the Moon will be recoverable. On NEO and Mars missions many of these same failures would be fatal to the crew resulting in billions of dollar in losses and multi-year stand downs.

The ability to safely sustain human life and equipment for long durations outside of the protection of Earth's magnetic field is an obvious stepping stone required by all missions beyond Earth. It makes sense then to build confidence in that capability where safe return times are measured in days in the case of Moon missions rather than months for NEO missions and even years for Mars missions. By methodically increasing our confidence in our systems as we go forward we will be able to reduce the cost and mass associated with added redundancy often used to insure against our ignorance and inexperience. At the same time it's equally important that the Moon not drive the design specification. The design specifications for the habitat and surface systems should be driven by the Mars and NEO missions requirements that also enable Lunar surface exploration. Long term it is envisioned that Lunar resource development, should that become an effective means to lower subsequent exploration costs, be maintained by systems remotely operated from Earth. When cost effective human Lunar landings may continue to happen from time to time for maintenance or upgrades to these surface systems.

Having achieved this advancement in our long duration space capability, precursor missions to Mars could be conducted that test all key aspects of a manned Mars surface mission except for the landing. One interesting mission would be to send a crew to the Mars vicinity (perhaps one of the moons of Mars) from which astronauts could control Mars surface robots in real time enabling a large number of potential landing sites to be canvassed and samples collected for return to Earth with the crew. In addition, these Mars surface robots could be landed via proto-type versions of a new class of Mars EDL systems needed before any manned Mars surface mission is attempted. With confidence in our surface systems tested on the Moon, deep space transit systems tested on NEO and Mars vicinity missions and advanced Mars EDL demonstrated, the stage will be set for mankind to safely and productively explore the surface of Mars.

A basic summary of the overall DIRECT plan is shown in Figure 1. While this was in the appendix of the presentation given to the committee on June 17th we could not provide an adequate explanation in the time allotted. An even more detailed technology roadmap is shown in figure 2. In summary, we would recommend that we protect our options by first protecting our heavy-lift, high volume launch system and workforce via the Jupiter. After that is accomplished studies in how to best to proceed can be fully explored and given the time they deserve. Perhaps the best summary of the DIRECT proposal is that by protecting one of our options today we enable the exploration of many more options far into the future.

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Figure 1: High Level Summary of the DIRECT Technology Roadmap

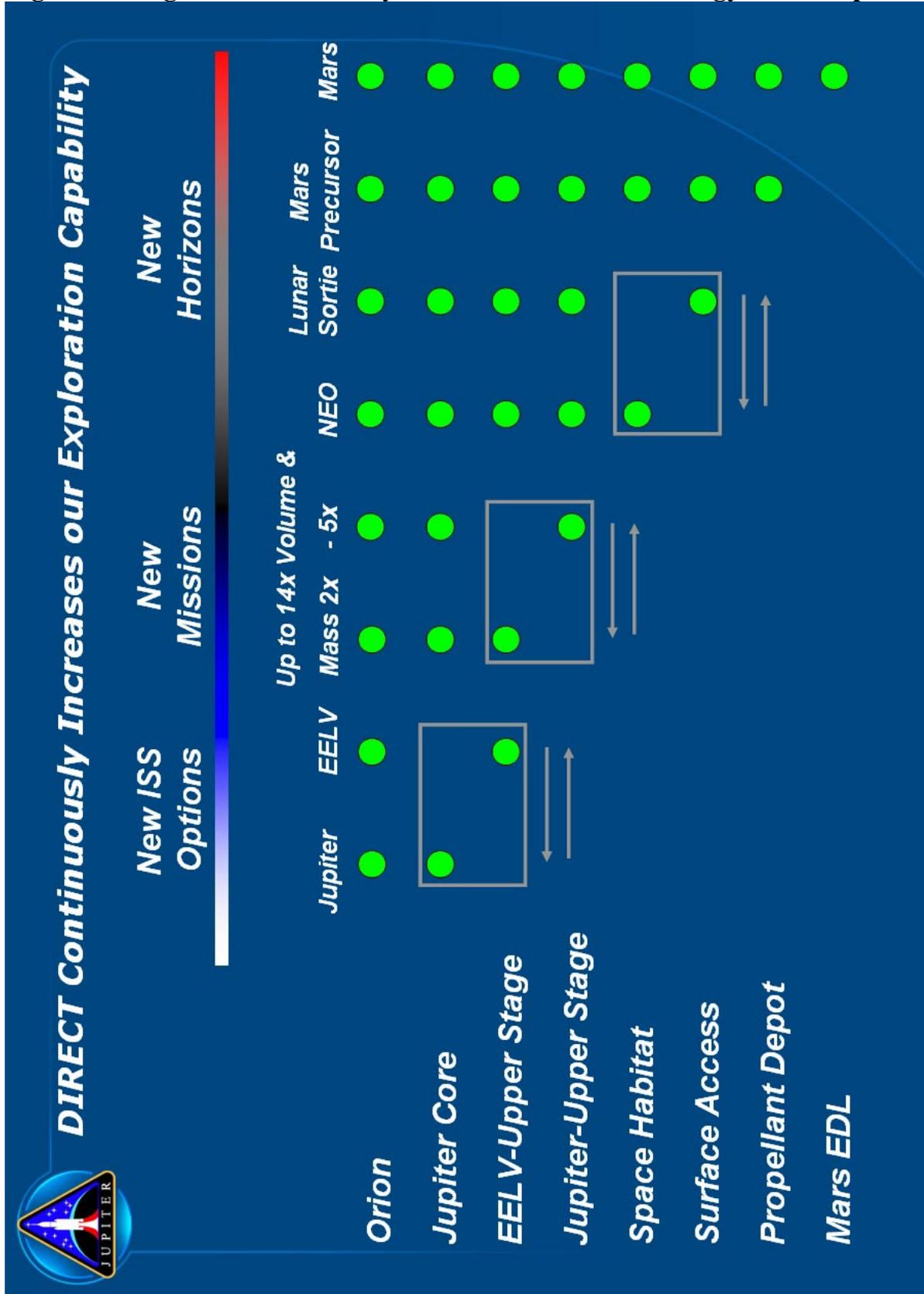


Figure 2: DIRECT Technology Roadmap

